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<b>13. ABSTRACT (Maximum 200 Words)</b>  We have elaborated a novel strategy for the self-assembly and co-assembly of functional supramolecular columns that self-organize in a hexagonal columnar liquid crystalline phase forming high carrier mobility organic semiconductor materials for applications in photorefractive and photovoltaic devices. Among our accomplishments are, (1) synthesis and elucidation of the structure of self-organizing dendron materials into a helical superstructure supporting an axial transport channel suggesting that structure and function can be separately tailored, (2) demonstration of high mobility carrier transport of nearly 10-2 cm <sup>2</sup> /Vs, (3) synthesis of robust glass forming self-organizing dendron materials, (4) control of ionization potential and electron affinity by synthetic methods using various donor and acceptor moieties, (5) demonstration of the photorefractive effect in appropriate composites, (6) demonstration of the photovoltaic effect in a nanostructured inorganic/organic composite cell, (7) elucidation of carrier generation and transport mechanisms in columnar and smectic liquid crystalline phases, and (8) high mobility carrier transport in polymer networks. Such arrays are applicable to devices spanning from single supramolecule to nanoscopic and to macroscopic scales including transistors, photovoltaics, photoconductors, photorefractives, light emissives, and optoelectronics.				
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## **I. Objective of Program:**

The program objective was to develop new classes of high carrier mobility photorefractive organic materials in order to improve the photorefractive properties of existing materials by 1) providing a faster response, and by 2) providing for operation at near-infrared communications wavelengths. As we found that the paucity of appropriate trapping in this materials leads to a weak photorefractive effect, we have begun to investigate the potential of these materials for photovoltaic devices.

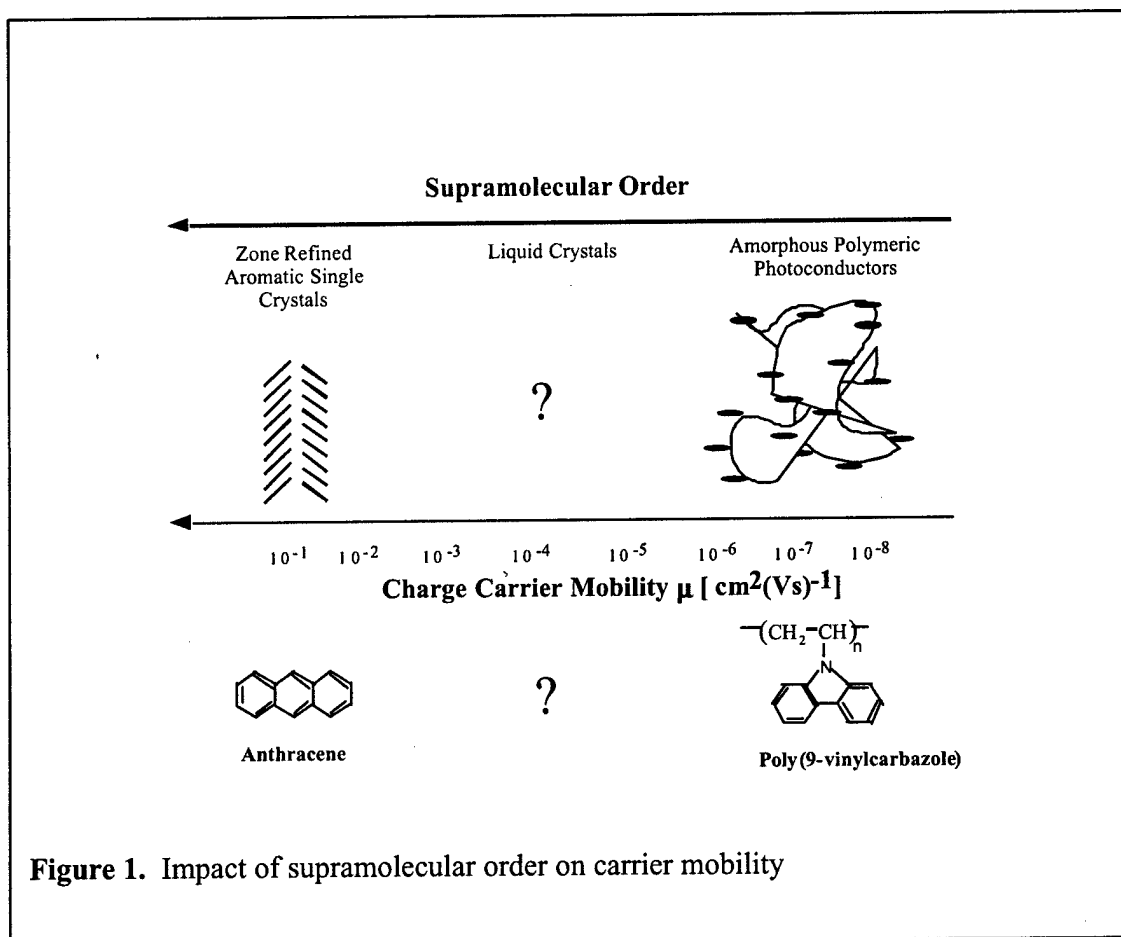
## **II. Approach:**

Photoconducting polymers have been the subject of considerable research due to their application as photoreceptors in photocopying technology. More recently, interest has developed semiconducting organic materials applications in electroluminescent, photorefractive, photovoltaic, and transistor devices.<sup>1</sup> There has been intense research recently into photorefractive polymers based on photoconducting polymers<sup>2,3,4,5,6,7</sup> and liquid crystals<sup>8,9</sup>. Each application has its unique requirements for such materials relating to the transport process. Thus the functions of photocarrier generation, transport and trapping will vary depending on application. Polymers are an ideal material in this regard, as different functionalities can be blended according to need. Since the physical mechanisms giving rise to these properties can vary, considerable variation in properties among polymers and other organic materials have been observed.

We have been pursuing research into photorefractive applications of photoconducting organic materials over the past six years. Our focus has been on increasing speed and long-wavelength sensitivity. We have made considerable progress in identifying candidate materials, as we will describe below. In particular, we have identified an exciting new class of materials possessing hole mobilities several orders of magnitude larger than polyvinyl carbazole composites (PVK). We found that inadequate trapping limits the photorefractive response. We have then turned our attention to photovoltaic applications of these materials.

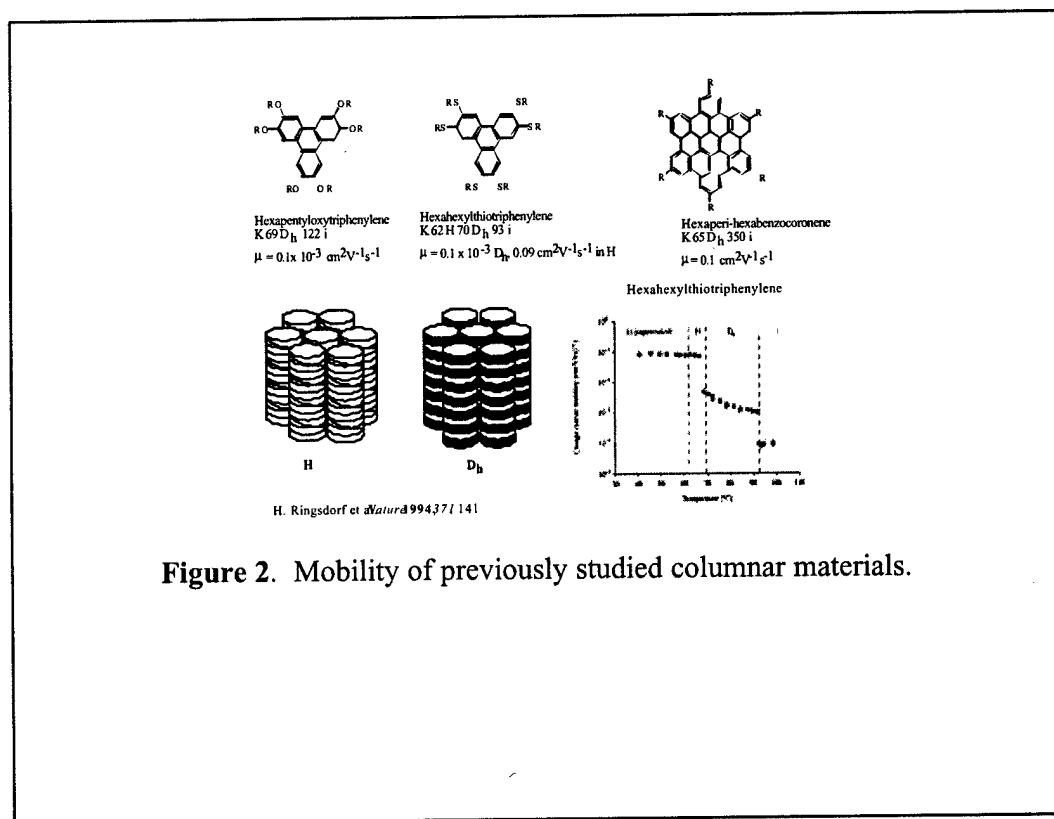
Figure 1 outlines the dependence of charge carrier mobility,  $\mu$ , [in  $\text{cm}^2/\text{Vs}$ ] in conventional photoconducting materials versus supramolecular order<sup>10,11</sup>. As expected,

the increase of order from that of an amorphous material like poly(9-vinylcarbazole) to an aromatic single crystal like anthracene induces and increases the mobility of up to seven orders of magnitude.



Both amorphous polymers and aromatic single crystals have advantages and disadvantages. The advantages of an amorphous polymer are: its excellent film forming properties, good mechanical properties, functional tailorability, and various processing capabilities. Its drawback consists mainly of its limited range of mobility. The advantage of a single crystal is its excellent mobility. However, the disadvantages of single crystals are: the high price of zone refined methodology for their preparation, lack of film forming properties and poor mechanical properties. An optimum technological compromise was accomplished with a solid solution of an amorphous polymer bisphenol-A polycarbonate) containing a low molar mass photoconducting material (N,N'-diphenyl-N,N'-bis(3-methylphenyl)-[1,1'-biphenyl]-4,4'-diamine (TPD)<sup>12</sup>.

As shown in Figure 1, the only other materials that can combine photoconductivity, order, processability and therefore are expected to provide very high mobility are liquid crystals. Ringsdorf *et al.* have demonstrated that discotic molecules like hexaalkoxytriphenylene and hexaalkylthiotriphenylene exhibit a high mobility for photoconductivity ( $\mu = 10^{-4} \text{ cm}^2/\text{Vs}$ ) in a discotic hexagonal disordered liquid crystalline ( $D_{hd}$ ) phase<sup>13,14,15</sup>. The mobility of hexahexylthiotriphenylene increases to  $9 \times 10^{-2} \text{ cm}^2/\text{Vs}$  in a more ordered H phase. Most recently, Müllen *et al.* have demonstrated a mobility of  $10^{-1} \text{ cm}^2/\text{Vs}$  in the discotic hexagonal ordered liquid crystalline phase of hexatetradecyl hexa-peri-hexabenzocoronene<sup>16</sup>. Figure 2 highlights these results. It is interesting to observe that the mobility in the H and  $D_{ho}$  phases (Figure 2) is approaching the values of aromatic single crystals (Figure 1). In our opinion this is not unexpected since the H and  $D_{ho}$  phases are not liquid crystalline but crystalline (Figure 1). These excellent results were however obtained on discotic molecules that are not easily synthesized and have limited synthetic capabilities concerning their insertion in

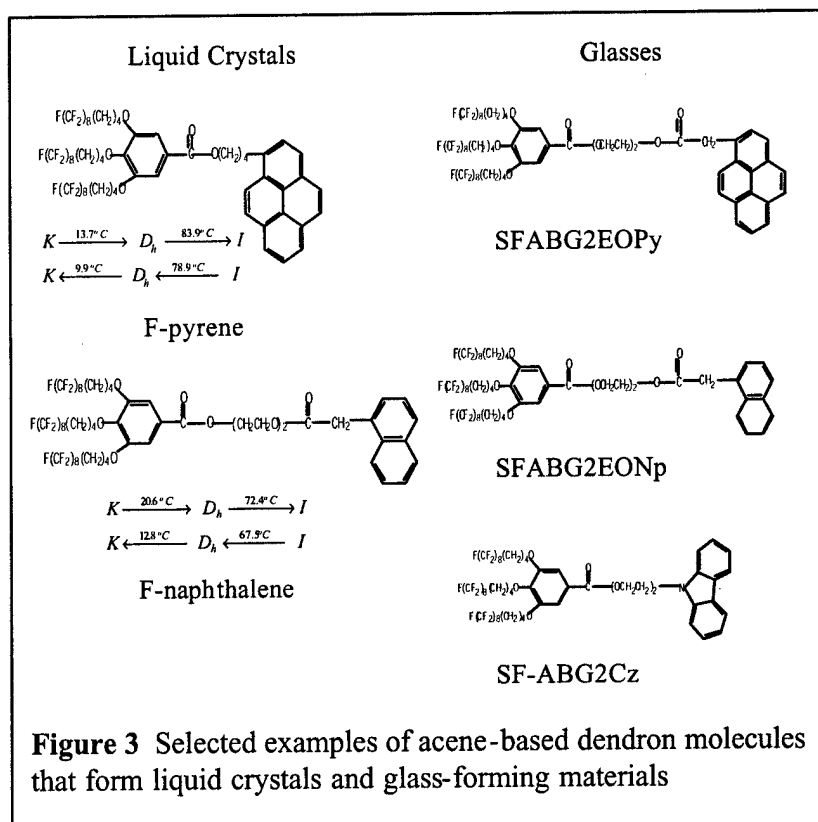


**Figure 2.** Mobility of previously studied columnar materials.

polymeric structures, photosensitization in different wavelength range by complexation or by blending with various additives in order to induce photorefractivity and other properties.

We have been investigating another approach to columnar liquid crystal structures which is decidedly more flexible in adjusting and adding functionality than the triphenylene systems. In the proposed work described here, we plan to 1) synthesize improved materials to further enhance the carrier mobility and sensitivity spectrum based on our concept of self-assembling columnar liquid crystal/polymer materials 2) characterize the basic photoconductive properties, such as mobility and charge generation toward an

understanding of the physical mechanisms leading to the enhanced properties observed to find new ways to improve materials and 3) introduce trapping and nonlinear optical moieties for improved photorefractive properties. We now describe some exciting first results, and the extensions of present work being proposed here.



### III. Accomplishments

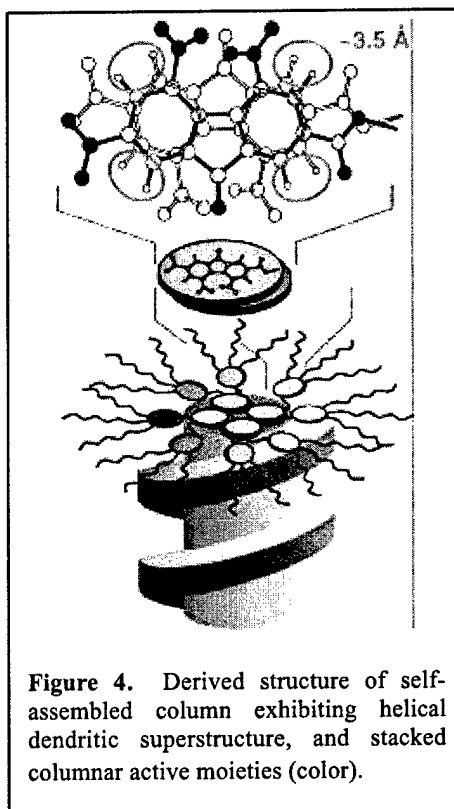
#### List of major accomplishments

- Synthesis and elucidation of structure of self-organizing dendron materials
- Demonstration of high mobility carrier transport (Publication in *Nature*)
- Synthesis of robust glass forming self-organizing dendron materials

- Control of ionization potential and electron affinity by synthetic methods
- Demonstration of photorefraction
- Demonstration of the photovoltaic effect in a composite cell
- Elucidation of carrier generation and transport mechanisms in columnar and smectic liquid crystalline phases
- High mobility carrier transport in polymer networks

### Self-organizing molecular dendrons

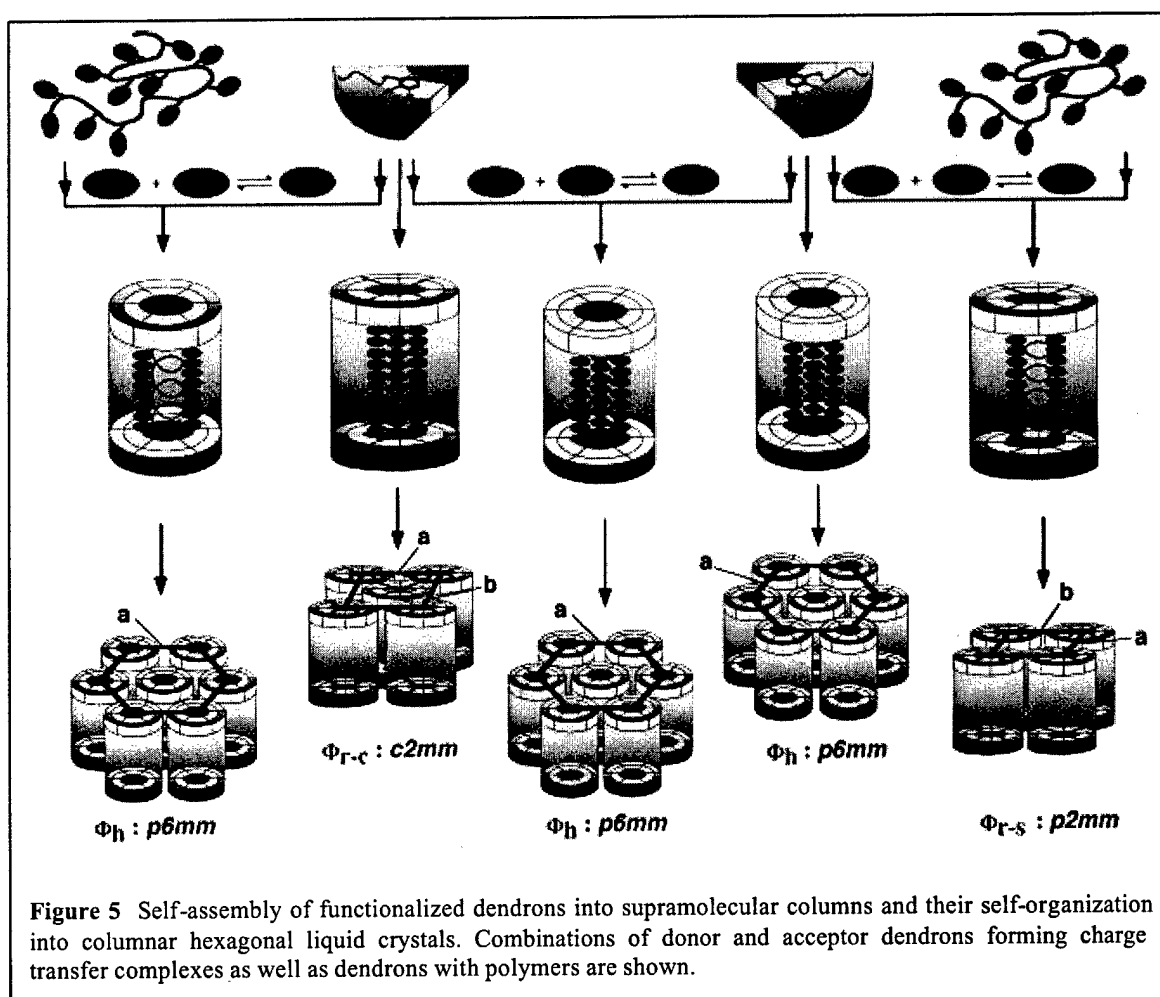
We have recently elaborated a novel strategy for the self-assembly and co-assembly of functional supramolecular columns that self-organize in a hexagonal columnar liquid crystalline phase<sup>17,18,19</sup>. The materials are built from dendritic monomers such as those shown in Figure 3 exhibiting a dendritic moiety and a functional taper group. As we have recently shown (Figure 4), these monomers self-assemble into columns in quite a fascinating manner.<sup>20</sup> The dendritic moieties self-assemble into a helical superstructure with four functional taper groups in the center. The taper groups stack in a column along the helical axis with their planes perpendicular to the axis. The stacking distance of 3.5 Å allows strong overlap of the pi-electron



**Figure 4.** Derived structure of self-assembled column exhibiting helical dendritic superstructure, and stacked columnar active moieties (color).

orbitals along the stacks. This structure applies to many of the taper groups that we have examined. The resulting structure is quite important and somewhat surprising. It is well-known, for example, that acene molecules arrange in a herringbone pattern in molecular crystals. Yet, in these dendritic columns, the acenes are stacked like poker chips. This fact has important implications, namely, that the structure is determined almost entirely by the dendritic moieties. *This implies that the design of the supramolecular structure and the electronic function are completely separate.* This important property allows for a wide variety of functional molecules to be incorporated into the columnar structure, as we

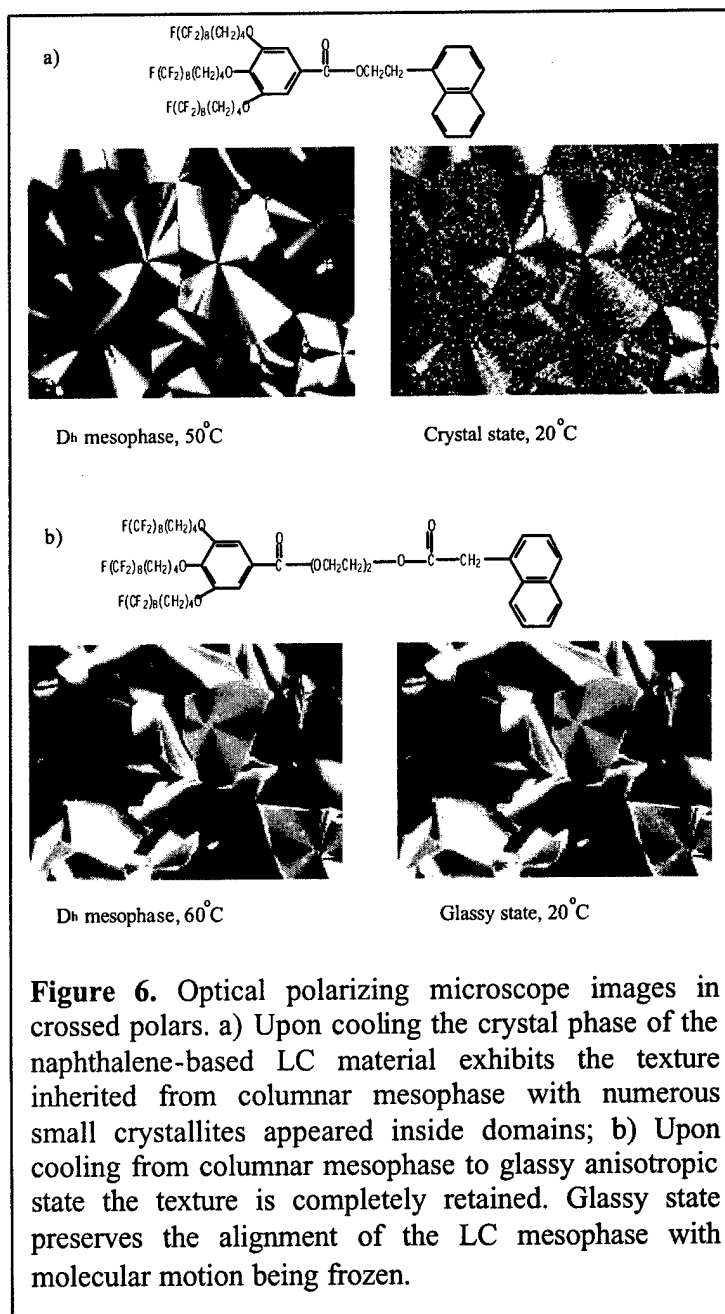
have, indeed demonstrated. This unprecedented tailorability is unique to this class of columnar materials. The columns self-organize into a hexagonal columnar liquid crystal phase, which can be aligned either in the plane (homogeneously) or perpendicular to the plane (homeotropic) of the substrate. When well-aligned, these columns form nanoscopic insulated semiconducting “wires”. We have been able to produce liquid crystal phases whose textures indicate a well-aligned homeotropic phase whose domain size is much larger than the film thickness, and on plastic substrates approach single domain size. This implies that transport proceeds completely from one electrode to the other. These wires exhibit semiconducting properties, and may prove to exhibit true one-dimensional behavior.



We have completed a study demonstrating the inherent flexibility of our approach. Figure 5 depicts how materials can be “mixed and matched” to produce

semiconducting systems of unusual flexibility. Dendrimers can be functionalized with electron donor, acceptors, and other moieties exhibiting a range of ionization potentials and can be combined with polymers to form liquid crystalline polymers. Figure 3 depicts the materials used in our initial studies based on donor and acceptor functionalized dendrimers and photorefractive composites. These composites based on carbazole donors and trinitrofluorinone

(TNF) acceptors have been mixed to form donor-acceptor complexes also with high carrier mobility about  $10^{-3} \text{ cm}^2/\text{Vsec}$ . Combinations with polymers as shown in Figure 5 have also been realized, that is, a combination of polyvinylcarbazole polymer with a TNF dendrimer, and a TNF polymer with a carbazole dendrimer. We have measured carrier mobilities in these materials, with selected results shown in Table 1. We have found that a variety of high carrier mobility materials for both electrons and holes can be attained. These values are comparable to other columnar





materials in similar hexagonal columnar phases. We have also found that composites of materials can be formed to enhance performance. For example, the charge generation efficiency in a number of hole transporters can be enhanced by two orders of magnitude by forming charge transfer complexes with a TNF functionalized dendrimer. In these studies, we found that the degree of in-plane order of the carbazole moieties is quite high. In fact, when we applied the electric field to the homeotropically aligned liquid crystal, the columnar order was disrupted by the coupling of the carbazole dipole to the electric field. This structural disruption resulted in the mobility decreasing with field. In order to eliminate this problem, we looked at a series of nonpolar transport agents based on acenes.<sup>20</sup> We investigated charge mobility in a series of acenes shown in Figure 2. We found that the structure was stable under electric field, and that the mobility remained nearly constant as the electric field was increased with magnitudes comparable to those observed in the carbazole-based materials. The time of flight mobility values for these materials are also given in Table 1.

We have proposed polaron transport mechanisms in this material, as well as in smectic liquid crystals.<sup>21,22</sup> Two models may be consistent with the data: (1) hopping of self-trapped polarons using the Holstein small polaron model in the nonadiabatic regime, and (2) competition between so-called nearly small molecular polarons and small lattice polarons. We have found it impossible to differentiate these models from each other or from an activated hopping model from localized states, in light of the narrow temperature range of the liquid crystal

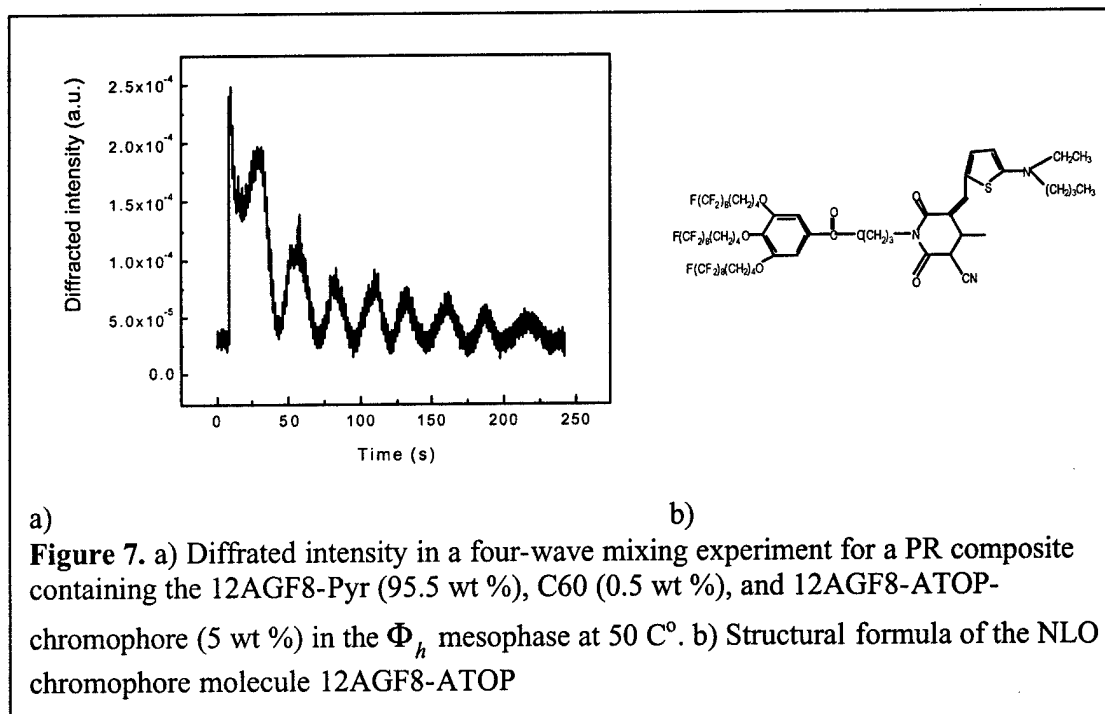
phase. We will describe these models in more detail below and how we plan to test them using anisotropic glasses.

Although our results indicate that this class of materials can produce high carrier mobility electronic materials, and their properties can be tailored, we have also

**Table 1.** Measured time of flight mobilities.

I. Material	Mobility (cm <sup>2</sup> /Vsec)
<b>Liquid crystals</b>	
12AGF8-Cz+12AGF8-TNF	1.6 X 10 <sup>-3</sup>
F-Pyrene	3.5 X 10 <sup>-3</sup>
F-naphthalene	1.5 X 10 <sup>-3</sup>
<b>II. Glass-forming</b>	
SF-ABG2EO-Py	9.4 X 10 <sup>-4</sup> (LC) 1.3 X 10 <sup>-3</sup> (glass)
ABG2EO-TNF	2.0 X 10 <sup>-3</sup> (LC) 2.2 X 10 <sup>-3</sup> (glass)

found that dipolar dendrimers can lead to electric field induced disorder, that the physical mechanism is difficult to study in the narrow liquid crystal temperature range, and that parasitic ionic drift can be present (as we describe just below). In addition, measurements in the liquid crystal state are carried out at elevated temperature ( $\sim 60^\circ\text{C}$ ). In addition, multilayer devices containing only materials with liquid crystalline order would be difficult to produce. We have recently discovered that all of these issues can be eliminated by using the materials in the glassy state. The formation of anisotropic glasses from columnar discotic phases has been discussed in the literature, but our results are the first to our knowledge describing electronic measurements on room temperature glasses, and the first report of devices constructed from them.<sup>23,24,25,26</sup> Following appropriate cooling from the liquid crystal phase, the glassy phase completely maintains the structure

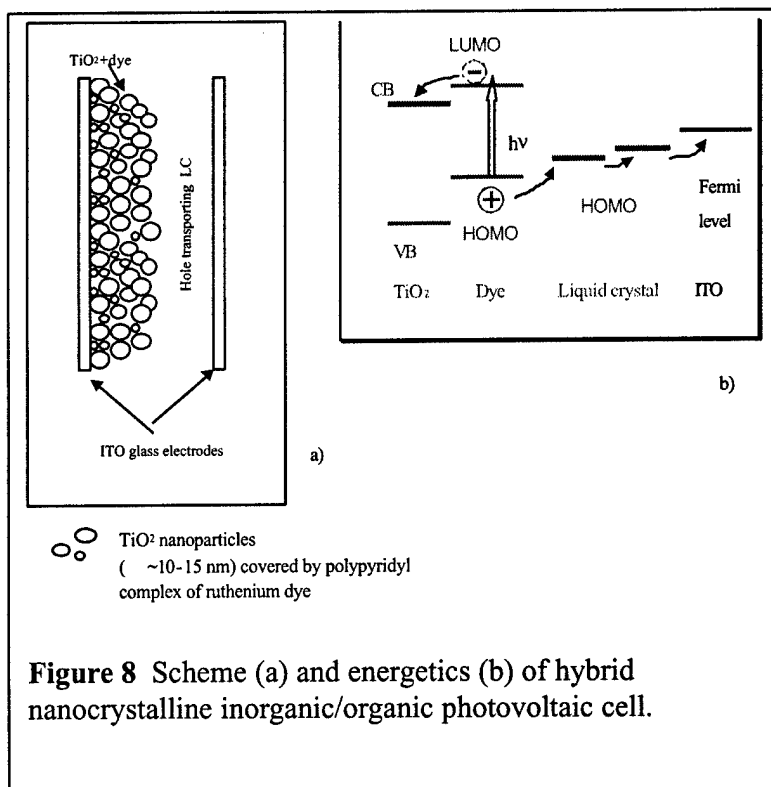


of the liquid crystal, which remains stable for several days. Stabilization of the glassy phase through polymerization will be an activity in this project. Figure 6 depicts polarizing micrographs of the indicated materials. In the upper set of pictures, the liquid crystal phase and the crystalline phase are shown. The small crystallites in the crystal phase are apparent. These crystallites are smaller than the film is thick, so that the interfaces produce significant trapping, leading to extremely dispersive transport, and

materials that are not appropriate for applications. In the bottom set of photographs the liquid crystal and glassy phases are shown. It is apparent here, that the glassy phase possesses the same homeotropic structure as that of the liquid crystal phase. Time-of-flight transients indicate nearly identical transport and hole mobility values in both the liquid crystalline and glassy phases as indicated in Table 1.

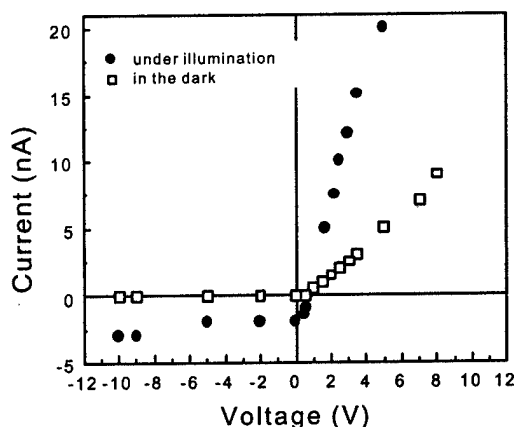
### Photorefraction in discotic liquid crystals and glasses.

We have made PR composites based on discotic LCs containing  $C_{60}$  and the nonlinear optical chromophore molecule 12AGF8-ATOP shown in Figure 7b. We used the 12AGF8-Pyr dendron as the hole transport material and 4.5% of 12AGF8-ATOP by weight as the responsive electro-optic chromophore. The compound  $C_{60}$  was added at 0.5% weight fraction in order to sensitize photocarrier generation in the visible by forming charge transfer complexes with the pyrene moiety. The result of the four-wave mixing experiment for the liquid crystal composite is shown in Figure 7a. The nature of the slow, strong oscillation in the LC phase is not understood in detail, but is likely due to grating drift arising from various factors including ionic and/or mass currents in the LC, and possibly a grating-like structure due to a thermo-optical effect. This oscillation can be eliminated by cooling the LC composite to the glassy state which exhibits a stable diffraction signal.



### Photovoltaic device

We have made a photovoltaic cell as shown in Figure 8 for preliminary evaluation<sup>27,28</sup>. The Grätzel cell is constructed so that the nanoporous  $\text{TiO}_2$  is the electron conducting path while the dendritic glass is the hole conducting path. The photoexcited polypyridil complex of ruthenium dye injects the electron into the conduction band of  $\text{TiO}_2$  and regenerates the neutral dye as an electron is donated from the liquid



**Figure 9.** Current-voltage characteristics for ITO/ $\text{TiO}_2$ /Ru535/PyreneLC/ITO cell.

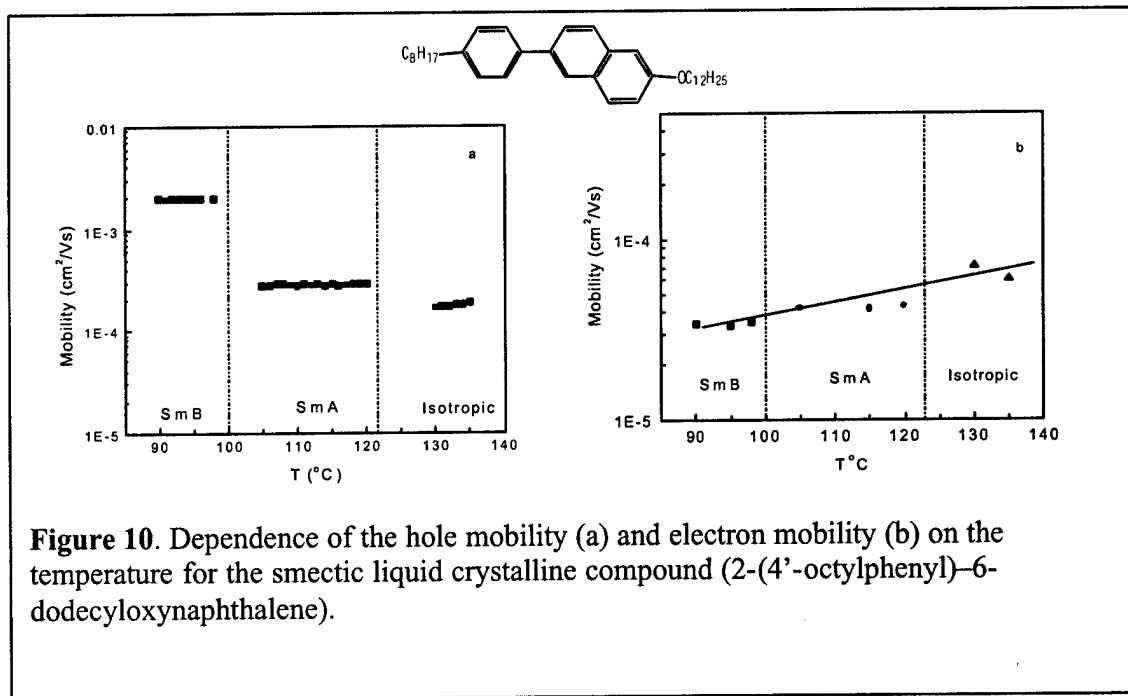
crystal glass. The photovoltaic effect is demonstrated by the preliminary data in Figure 9 with an open circuit voltage of about a  $\frac{1}{2}$  volt. We found similar operation in both the liquid crystal and glassy phases. The current, and thus the converted power is low due to poor coverage of Ruthenium dye incorporated into the cell in this first attempt, and to an imperfect matching of energy levels. As we perfect the fabrication process and synthesize hole-transport materials with lower ionization potential, we expect the efficiency to improve markedly and expect the performance similar or better than recent work due to enhanced carrier mobility and superior design. The LC dendrimer molecules with high hole mobility could enhance charge separation and reduce recombination losses from photoexcited electrons at the dye/LC interface due to the rapid hole removal from this interface. Moreover the dendrimer molecules are able to provide a better interface with the nanocrystalline film due to their easy penetration in the liquid isotropic state.

### Electronic transport in smectic liquid crystals.

By measuring transient photoconductivity, we have shown that the smectic liquid crystalline material 8PNPO12 (2-(4'-octylphenyl)-6-dodecyloxy-naphthalene) exhibits a fast ambipolar electronic transport (LC materials were synthesized by Robert Twieg, Kent State University) We have found that hole transport was intrinsic with a high hole

mobility of  $10^{-3} \text{ cm}^2/\text{Vs}$ . The hole mobility was sensitive to smectic molecular order (Figure 10), which determines the hopping rate between neighboring molecules. We have proposed that hole transport can be considered as a small polaron formed by localized carriers and induced electronic and molecular polarization, moving as a quasi-particle between hopping sites. We have described the temperature independent mobility in the smectic mesophase in the framework of the nonadiabatic limit of the Holstein small polaron model. We have shown that the hole mobility is sensitive to the transfer integral that is influenced by molecular orientation and motion in the smectic LC mesophases, and have suggested that another possible explanation of the temperature independent mobility can be a contribution into the mobility of two coexisting polaron mechanisms: nearly small molecular polarons (Silinsh <sup>29, 30</sup>) and small lattice polarons. To distinguish these mechanisms, LC materials exhibiting broad mesophase temperature ranges should be studied. Electron transport was not sensitive to molecular orientation and exhibited thermally activated mobility, which is governed by shallow trapping due to impurities. The rate-limiting factor for electron transport is the lifetime of trapping sites. We have treated the temperature-activated electron mobility in the framework of the Bässler disorder formalism.

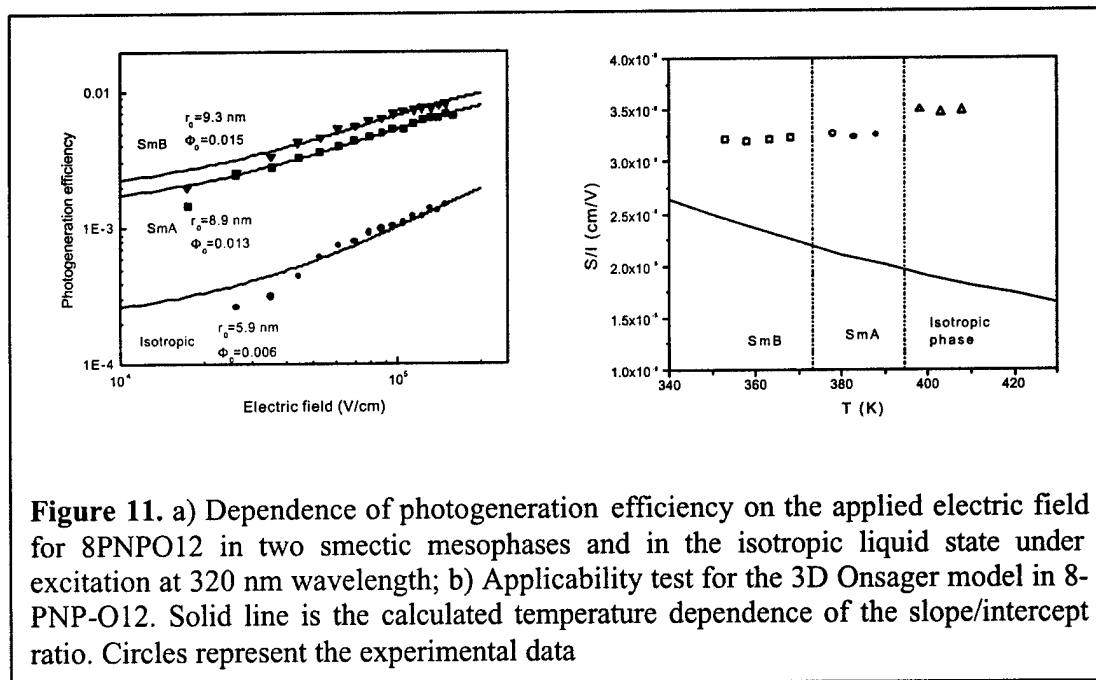
In summary, the temperature independent mobility strongly indicates that the



intrinsic transport mechanism in the liquid crystalline materials is likely to be the polaron hopping. To establish the exact polaron mechanisms, experiments with various smectic liquid crystals having a broader temperature range should be performed. As we demonstrated, the purity of the LC materials is a very important issue because impurity induced trapping transport can obscure the inherent fast transport mechanisms in the LCs. A complete theoretical description of polarons in LCs is still lacking and it is of fundamental importance to have a comprehensive theory to understand the underlying transport mechanisms. The classical Holstein model and the Silinsh model should be reconsidered to take into account quasi 2D transport in smectic liquid crystalline materials. The relationship between molecular organization and charge transport also requires further exploration.

### Photogeneration in smectic liquid crystals

We have carried out preliminary measurements of extrinsic photogeneration efficiency in the smectic (2-(4'-octylphenyl)-6-dodecyloxynaphthalene) LC compound photosensitized by  $C_{60}$  molecules using the xerographic discharge technique. The sample surface was contact charged, and the discharge rate was measured in the dark and under illumination using low intensity radiation from a He-Ne laser with  $\lambda=632.8$  nm. The intrinsic photogeneration efficiency was determined using time-of-flight photocurrent



**Figure 11.** a) Dependence of photogeneration efficiency on the applied electric field for 8PNPO12 in two smectic mesophases and in the isotropic liquid state under excitation at 320 nm wavelength; b) Applicability test for the 3D Onsager model in 8-PNP-O12. Solid line is the calculated temperature dependence of the slope/intercept ratio. Circles represent the experimental data

transients excited by 320 nm wavelength laser pulses from a frequency doubled and stimulated Raman shifted Nd:YAG laser. It appeared that photogeneration efficiency is sensitive to the molecular order within the LCs mesophase (Fig.11a). Solid lines in Figure 11a show the fit of the experimental data to the 3D Onsager model, which considers the charge generation process as a two-step event without specifying the microscopic mechanism of photogeneration. In the first step, an absorbed photon excites a bound electron-hole pair. The electron, whose kinetic energy exceeds  $kT$ , thermalizes losing its energy to the medium. This step is characterized by an initial thermalization distance (or a pair separation)  $r_0$  and a field-independent primary quantum yield  $\Phi_0$ , which is the ratio between the number of absorbed photons, which generates the bound electron-hole pairs, and the total number of absorbed photons. The next step is the field-dependent dissociation of the thermalized bound pairs into free charge carriers in the potential of the Coulomb interaction and applied electric field. The bound pairs either dissociate or undergo the geminate recombination to the ground state.  $\Phi_0$  increase with increasing molecular order in the system. The measured photogeneration efficiency is in good agreement with the theoretical fit in the high field region. However, as can be seen from Fig.11a the fit notably deteriorates at low field where the predicted efficiency exceeds the experimental data. In another discrepancy with the Onsager model, the photogeneration efficiency was found to be temperature-independent within the smectic mesophases. This contradicts the temperature-dependent photogeneration predicted by the Onsager model. This theory predicts an exponential dependence on reciprocal temperature, which has been successfully observed for isotropic molecular systems<sup>31</sup>.

The applicability of 3D Onsager model can be tested by calculating a slope-intercept ratio,  $\frac{S}{I} = \frac{e^3}{2\pi\epsilon k^2 T^2}$  of the field dependence of the photogeneration efficiency at low electric field. The value of the slope-intercept ratio should be only dependent on the temperature and the dielectric constant. The temperature dependence of the calculated slope-intercept ratio for experimental value  $\epsilon = 2.3$  is shown in Figure 11b. It can be seen that the slope-to-intercept ratios obtained with the Onsager model (solid line) do not agree with that from experimental data (data points).

Our results clearly manifest inapplicability of the 3-D Onsager model with isotropic symmetrical initial distribution of electron-hole distances neither to the quasi two-dimensional smectic liquid crystalline mesophase nor to the isotropic liquid state. There are two suggested explanations for this discrepancy. First, it has been recognized that the Onsager model often results in unrealistically large thermalization distances due to the initial assumption that the electron-hole pair recombines instantaneously when the pair separation distance approaches zero <sup>32</sup>. Second, the Onsager model was developed initially for charge photogeneration in isotropic media. It has been shown that the dimensionality of some polymeric photoconductive systems may cause an orientation-dependent dissociation probability which cannot be described by a 3D theory and requires the formulation of the 1D Onsager theory <sup>33, 34, 35</sup>. Moreover the orientation of the initial electron-hole pairs can be anisotropic in the applied electric field due to the nonzero dipole moment <sup>36</sup>. The smectic mesophase is quasi two-dimensional system, which might necessitate a revision of the 3D Onsager model.

#### Transport in polymer networks.

Our recent studies of electronic charge transport in conjugated organometallic polymer networks based on EHO-OPPE (poly(p-phenylene ethynylene, PPE derivative) cross-linked with Pt<sup>0</sup> have revealed a high ambipolar charge carrier mobility of  $10^{-2}$  cm<sup>2</sup>/Vs<sup>39,40</sup>, which is one of the highest mobility yet observed in disordered conjugated polymers. The introduction of conjugated cross-links between the conjugated macromolecules leads to a substantial increase of the charge carrier mobility of neat polymer. The data shown in Fig. 12 show that the carrier mobility strongly increases upon introduction of Pt<sup>0</sup>. The positional (off-diagonal) and energetic (diagonal) disorder parameters have been calculated from the experimental temperature and field dependences of the hole and electron mobilities. The observed negative field dependence of the mobility (Fig.12) was explained within the Gaussian disorder formalism to originate from high off-diagonal disorder. The experimental temperature and field dependent mobilities are consistent with a Gaussian disorder transport formalism applied to systems exhibiting both positional and energetic disorders.



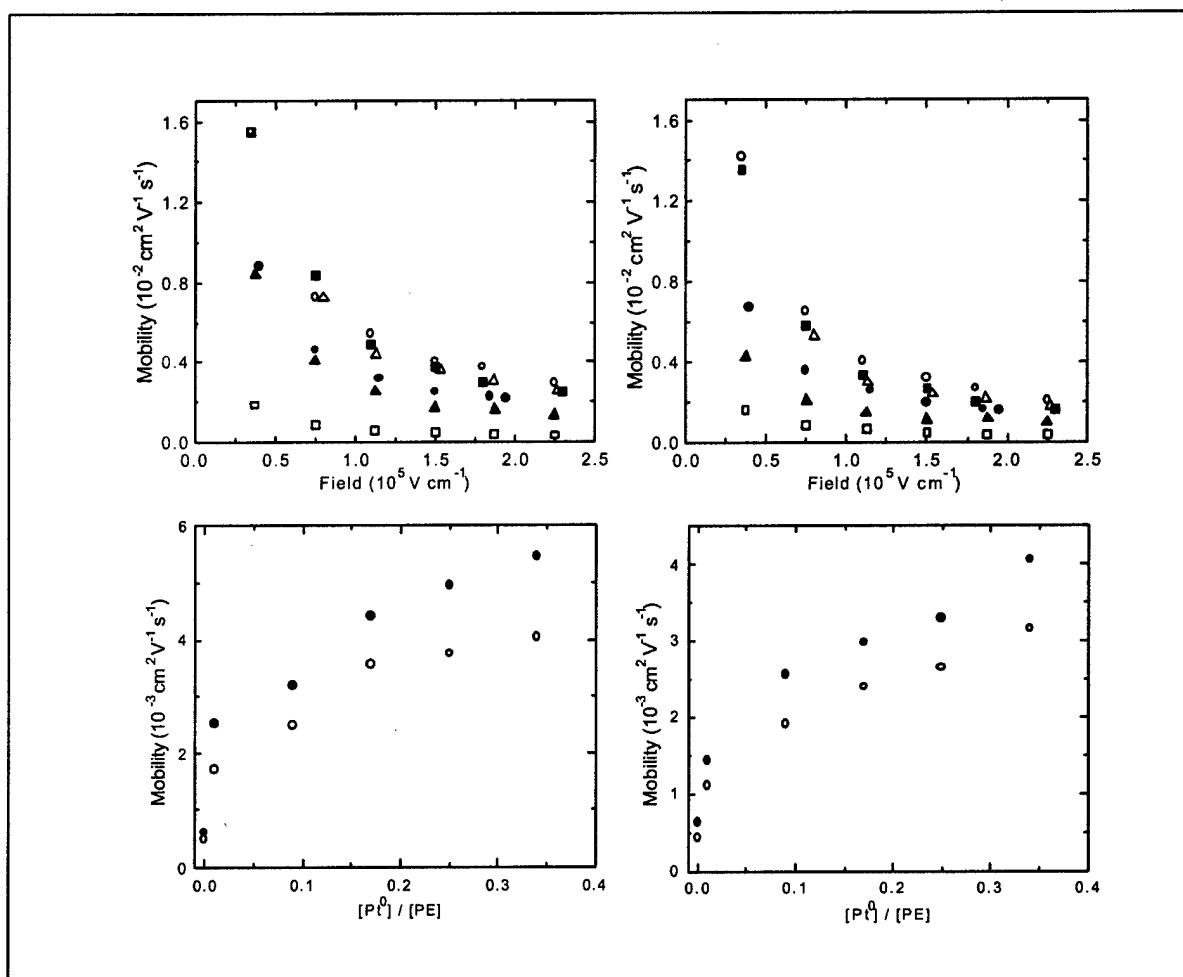


Figure 12. Electron (top left) and hole (top right) mobility of EHO-OPPE- $\text{Pt}^0$  as function of  $[\text{Pt}^0]/[\text{PE}]$  and electric field  $F$  ( $[\text{Pt}^0]/[\text{PE}]$ : =0, =0.016, =0.086, =0.17, =0.25, =0.34). Electron (bottom left) and hole (bottom right) mobility at  $F = 1.1 \cdot 10^5$  ( ) and  $1.5 \cdot 10^5 \text{ V cm}^{-1}$  ( ) as function of  $[\text{Pt}^0]/[\text{PE}]$ .

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#### IV. Personnel Supported

Jingwen Zhang, Research Associate (with K. Singer)  
Irina Shiyankovskaya, Research Associate (with K. Singer)  
Martin Glodde, Postdoctoral Researcher (with V. Percec)  
Yoshiko Miura, Postdoctoral Researcher (with V. Percec)  
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#### V. Publications

1. V. Percec, M. Glodde, T. K. Bera, Y. Miura, I. Shiyankovskaya, K. D. Singer, V. S. K. Balagurusamy, P. A. Heiney, I. Schnell, A. Rapp, H.-W. Spiess, S. D. Hudson, and H. Duan, "Self-organization of supramolecular helical dendrimers into complex electronic materials," *Nature*, **419**, 384-387 (2002).
2. I. Shiyankovskaya, K.D. Singer, V. Percec, T.K. Bera, Y. Miura, and M. Glodde, "Charge Transport in Hexagonal Columnar Liquid Crystals Self-Organized from Supramolecular Cylinders Based on Acene Functionalized Dendrons," *Phys. Rev. B*, **67**, 035204 (2003).
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5. Oksana Ostroverkhova and Kenneth D. Singer, "Space-charge dynamics in photorefractive polymers," *J. Appl. Phys.* **92**, 1727-1743 (2002).
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9. "A Universal Strategy to Cylindrical Supramolecular Dendrimers Self-Organized in High Charge Carrier Mobility Materials", 224th American Chemical Society National Meeting, August 18-22, 2002, Boston, Massachusetts; Polym. Preprints, 2002, 43(2), 402-403.
10. Valeriy Boichuk, Sergey Kucheev, Janusz Parka, Victor Reshetnyak, Yuriy Reznikov, Irina Shiyankovskaya, Kenneth D. Singer, and Sergey Slussarenko, "Surface-Mediated Light-Controlled Friedericksz Transition in a Nematic Liquid Crystal Cell," *J. Appl. Phys.* **90**, 1858-1862 (2001).
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## VI. Interactions/Transitions

1. "Carrier Transport in Self-Organizing Molecular Semiconductors," **K.D. Singer**, Cornell University, October 10, 2002.
2. "Molecular Electronics in Self-Organizing Semiconducting Materials," **K.D. Singer** CWRU, September 12, 2002.
3. K.D. Singer, "Molecular Semiconductors," Kent State University, March 13, 2002.
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5. K.D. Singer and O. Ostroverkhova, "Influence of composition on the photoconductive and photorefractive properties of PVK composites," *Proc. SPIE* **4462**, 163-177 (2001).
6. Irina Shiyankovskaya, Kenneth D. Singer, Virgil Percec, Tushar K. Bera, Yoshiko Miura, and Martin Glodde, "Electronic Transport in Self-Organizing Columnar Phases," *Proc. SPIE* **4991** (2003).
7. K.D. Singer, I. Shiyankovskaya, and V. Percec, "Self-organizing semiconducting anisotropic glasses and liquid crystals," International Liquid Crystal Conference, 2002, June, 2002.
8. K.D. Singer and O. Ostroverkhova, "Modeling and design of photorefractive polymer composites," ICONO6, Tucson, December 2001.
9. Shiyankovskaya, K.D. Singer, V. Percec, M. Obata, Y. Miura, L. R. J. Twieg, V. Gettwert, S. Gu, L. Sukhomlinova, "Nanostructured Liquid Crystalline Semiconductor Materials," *Proc. SPIE* (2001).

10. Oksana Ostroverkhova, Kenneth D. Singer, Ludmilla Sukhomlinova and Robert J. Twieg, "Photoconductive Mechanisms in the Dynamic Photorefractive Response in Polymer Composites," Organic Thin Films for Photonics Applications, ACS-OSA, Washington, DC, August, 2000.
11. J. Zhang, V. Ostroverkhov, K.D. Singer, V. Reshetnyak, and Yu. Reznikov, "Surface Mediated Photorefractive Mechanisms in Liquid Crystals," ICONO'5, Davos, Switzerland, March, 2000.
12. O. Ostroverkhova, J. Zhang, and K.D. Singer, Sukhomlinova, R.J. Twieg, "Photorefractive Mechanisms in Liquid Crystal and Polymer Composites", Organic Thin Films for Photonics Applications, Santa Clara, September 24-26, 1999.
13. "Self-Control Aided Rational Design of Single Molecule Based Nanoarchitectures" by **V. Percec**, Invited Lecture, The 62nd Okazaki Conference: Structural Hierarchy in Molecular Science from Nano- and Meso-Structures to Microstructures, Okazaki, Japan, January 10-13, 1999.
14. "Combinatorial Libraries of Dendrimers" by **V. Percec**, Invited Lecture, Knowledge Foundation Conference on Combinatorial Approaches for New Materials Discovery, San Jose, CA, January 21-22, 1999.
15. "Superstructured Polymers" by **V. Percec**, Invited Lecture, Workshop on Nanostructured Materials and Technologies, Defense Sciences Research Council, Arlington, VA, March 16, 1999.
16. "A Universal Strategy for the Generation of Fast Photoconductivity in Conventional Organic Photoconductors Via Self-Assembly, Co-Assembly and Self-Organization into Supramolecular Columnar Liquid Crystals" by **V. Percec**, B. B. De, W-D. Cho, K. D. Singer, and J. Zhang, International Symposium: Synthesis of Novel Polymeric Materials, American Chemical Society Div. of Polym. Mat. Sci. Eng., Anaheim, CA, March 21-25, 1999. *PEMSE*, 80, 262-264 (1999).
17. "Nature as a Model for the Design of New Organic Materials" by **V. Percec**, Plenary Lecture, Vaalsbrock Scientific Meeting: Life Sciences and Materials, Vaalsbrock, The Netherlands, April 1-2, 1999.
18. "Constructing a Polymer Science Made of Giant Spherical and Cylindrical Visualizable Macromolecules Produced from Backbones Coated with Libraries of Self-Assembling Monodendrons" by **V. Percec**, Plenary Lecture, Europolymer Conference 1999: Regular Macromolecular Structures Based on the Controlled Polymerization Processes, Gargnano, Italy, May 23-28, 1999.

19. "A Universal Strategy for the Rational Design of Functional Supramolecular Dendrimers which Exhibit Externally Regulated Shape Changes" by **V. Percec**, MURI, Aberdeen, MD, June 10-11, 1999.
20. "Single Molecule Based Nano-Systems" by **V. Percec**, Invited Lecture, International Forum on Type-Structured Molecules, Kanagawa, Japan, June 29-July 1, 1999.
21. "Nature as a Model for the Rational Design of Novel Shape Persistent Architectural Motifs" by **V. Percec**, Invited Lecture, Gordon Research Conference on Polymers, Oxford, United Kingdom, July 4-8, 1999.
22. "Scope and Limitation in the Design of Functional Nano- Objects Undergoing Reversible and Irreversible Shape Changes" by **V. Percec**, Plenary Lecture, SMARTON: Structuring, Manipulation, Analysis and Reactive Transformation of Nanostructures, Graz, Austria, September 25-28, 1999.
23. "Libraries of Self-Assembling Dendrons as Building Blocks for the Rational Design of Complex Nanoarchitectures" by **V. Percec**, Invited Lecture, DECHEMA 1st International Dendrimer Symposium, Frankfurt, Germany, October 3-5, 1999.
24. "Nature as a Model for the Construction of New Concepts in Molecular, Macromolecular, and Supramolecular Materials" by **V. Percec**, Invited Lecture, International Symposium: Life Sciences and Materials ... Successful Marriage or Divorce? , San Giuliano Terme, Pisa, Italy, October 6-9, 1999.
25. "Viruses as Model for New Macromolecular Architecture" by **V. Percec**, Invited Lecture, Symposium Emerging Opportunities in Polymer Technologies, Cincinnati, OH, October 14-15, 1999.
26. "Nature as a Model for the Rational Design of Complex Nano-Systems" by **V. Percec**, University of Delaware, DE, November 16, 1999.
27. "Materials Designed with Secondary Chemical Bonds: Self-Assembly and Self-Organization" by **V. Percec**, Nature as a Model for New Functional Nanostructures, Invited Lecture, Workshop, DuPont Country Club, Wilmington, DE, November 22, 1999.
28. "Dendritic Macromolecules", by **V. Percec**, Royal Institute of Technology, Stockholm, Sweden, December 4, 1999.
29. "Hyperbranched Polymers", by **V. Percec**, Royal Institute of Technology, Stockholm, Sweden, December 4, 1999.
30. "Polymer Chemistry in the 21<sup>st</sup> Century", by **V. Percec**, Royal Institute of Technology, Stockholm, Sweden, December 6, 1999.



31. "Dendritic Liquid Crystals", by **V. Percec**, Royal Institute of Technology, Stockholm, Sweden, December 6, 1999.
32. "Complex Organic Synthesis via Living Radical Polymerization" by **V. Percec**, Invited Lecture, US-Japan Seminar on Polymer Synthesis, University of California, Berkeley, CA, December 12-15, 1999.
33. "Nature as a Model for the Construction of Nanosystems" by **V. Percec**, Chemistry Department, University of Toronto, Canada, January 7, 2000.
34. Supramolecular Membranes, by **V. Percec**, ONR, Washington DC, January 11, 2000.
35. "Nature as Model for the Design of Single Molecule Functional Nanosystems" by **V. Percec**, Invited Lecture, 50<sup>th</sup> Anniversary of the Makromolekulares Kolloquium, Freiburg, Germany, February 24-26, 2000, Abstracts, p.1
36. "Nature as a Model for the Development of New Concepts in Polymer Science", by **V. Percec**, DuPont Marshal Lab., Philadelphia, March 7, 2000.
37. "Complex Organic Synthesis via a Combination of LRP and Termini", by **V. Percec**, Invited Lecture, ACS San Francisco, March 26-30, 2000, *Polymer Preprints* 41(1), 2000.
38. "Nature as a Model for the Design of Functional Nanosystems", by **V. Percec**, University of California, Department of Chemistry, Los Angeles, April 6, 2000
39. "Nature as a Model for the Elaboration of New Concepts in Polymer Science", by **V. Percec**, LG Chem., Research Park, Taejon, Korea, April 17, 2000.
40. "Nature as a Model for the Construction of a Polymer Science Made of Visualizable Chains", by **V. Percec**, Department of Chemistry, Seoul National University, Seoul Korea, April 19, 2000
41. "From Metal Catalysis to Autocatalysis", by **V. Percec**, Invited Lecture, International Symposium "From Metal Catalysis to Biocatalysis", Philadelphia, April 28, 2000.
42. "Nature as a Model for the Development of New Concepts in Polymer Science", by **V. Percec**, Invited Lecture, International Symposium of the Polymer Society of Sweden Dedicated to the 80<sup>th</sup> Birthday of Professor B. Ramby, Stockholm, Sweden, May 2-3, 2000.
43. "Detecting the Shape Change of Complex Macromolecules during Their Synthesis with the Aid of Kinetics. A New Lesson from Biology", by **V. Percec**, University of Ulm, Germany, June 2 2000.

44. "Nature as a Model for the Rational Design of Complex Nanosystems", by **V. Percec**, Invited Lecture, Discussion Meeting on Multi-Level Ordering by Competitive Short and Long Range Interactions in Macromolecular Systems, Weingarten, Germany, June 3-8, 2000.
45. "Persistent Motion of Monodendron Jacketed Linear Chains on Surface." by S.A. Prokhorova, B. Tartsch, S.S. Sheiko, M. Moeller, M. Holerca and **V. Percec**, P.50 Discussion Meeting on Multi-level Ordering by Competitive Short and Long Range Interaction in Macromolecular Systems, Weingarten, Germany, June 3-8, 2000.
46. "Single Molecules. From Science Fiction to Science." Invited Lecture, by **V. Percec**, Gordon Research Conference on Polymers (East), Connecticut College, New London, CT, June 10-15, 2000.
47. "Phase Behavior and Transitions in Polymers Comprising Amphiphilic Monomers." H. Duan, S.D. Hudson, P. Kewsuwan, **V. Percec** and M.N. Holerca, Gordon Research Conference on Polymers (East), Connecticut College, New London, CT, June 10-15, 2000.
48. "Nature as a Model for the Design of Complex Nanosystems." Invited Lecture, by **V. Percec**, European Polymer Federation Workshop on "Controlled Architectures and Supramolecularity of Polymers, Paris, France, June 19-20, 2000, Program and Abstracts L9.
49. "Nature as a Model for New Architectural Motives", by **V. Percec**, Eindhoven University, Eindhoven, The Netherlands, June 28, 2000.
50. "Nature as a Model for the Elaboration of New Concepts In Polymer Science." Plenary Lecture, by **V. Percec**, World Polymer Congress, IUPAC Macro 2000, 38th Macromolecular IUPAC Symposium, Warsaw, Poland, July 9th-14th, 2000; Book of Abstracts, Vol. 1, p. 19 (2000).
51. "Temperature Behavior of Columnar Self-Assemblies of Polymethacrylates and Their Macromonomers with Highly Tapered Side Groups." by S.N. Chvalun, M.A. Shcherbina, I.V. Bykova, J. Blackwell, Y.K. Kwon, J.D. Cho and **V. Percec**, world Polymer Congress, IUPAC Macro 2000, 38th Macromolecular IUPAC Symposium, Warsaw, Poland, July 9th-14th, 2000; Book of Abstracts, Vol 3, p.1100(2000).
52. "Single Molecule Based Electronically Active Elements." Plenary Lecture by **V. Percec**, International Conference on Science and technology of Synthetic Metals, ICSM 2000, Gastein, Austria, 15<sup>th</sup> to 21<sup>st</sup> of July 2000, Book of Abstracts, p.147(2000). Elsevier, New York.
53. "Supramolecular Photorefractive Materials." Invited Lecture by **V. Percec**, AFOSR Photorefractive Polymer Symposium, San Diego, CA, July 27-28, 2000.

54. "Nature as a Model for the Elaboration of New Concepts in Polymer Science." Invited Lecture by **V. Percec**, ACS Washington, D.C. August 20-24, 2000, *Polym. Mat. Sci. Eng.* **83**, 554(2000).
55. "Nature as a Model and Monodendrons as Building Blocks for the Design of Single Molecule Based Nanosystems." Invited lecture by **V. Percec**, National Institute of Science and Technology, Gaithersburg, MD, October 11, 2000.
56. "Nature as a Model for the Design of Complex Nanosystems." Invited Lecture by **V. Percec**, Department of Chemistry, Drexel University, Philadelphia, PA, October 25, 2000.
57. "Complex Organic Synthesis by Living Radical Polymerization." Invited Lecture by **V. Percec**, LG Chem, Korea, October 30, 2000.
58. "Nature as a Model for the Elaboration of New Concepts in Chemical Sciences." Plenary Lecture by **V. Percec**, Symposium Dedicated to the 40<sup>th</sup> Anniversary of the National Hellenic Research Foundation, Institute of Organic and Farmaceutical Chemistry, Athens, Greece, December 19, 2000.
59. "Nature as a Model for the Elaboration of New Concepts in Chemistry." Invited Lecture by **V. Percec**, Department of Chemistry, Tulane University, New Orleans, March 21, 2001.
60. "Molecular, Macromolecular and Supramolecular Liquid Crystals with Complex Architecture." Invited Lecture by **V. Percec**, European Liquid Crystal Conference, University of Halle, Germany, March 25-30, 2001.
61. "Complex Macromolecular Architecture with the Aid of Supramolecular Chemistry." Invited Lecture by **V. Percec**, 8<sup>th</sup> Dresden Polymer Discussion, Meissen, Germany, April 23-26, 2001.
62. "Nature as a Model for the Elaboration of New Concepts at the Interface between Organic, Supramolecular and Macromolecular Chemistry." Invited Lecture by **V. Percec**, Department of Chemistry, University of California, Irvine, CA, May 16, 2001.
63. "Nature as a Model for the Design of Nanosystems." Invited Lecture by **V. Percec**, IBM, Almaden Research Center, San Jose, CA, May 18, 2001.
64. "Nature as a Model for the Design of Nanostructured Liquid Crystals." Invited Lecture by **V. Percec**, International Symposium Nanostructured Liquid Crystals, Kent State University, Kent, OH, June 19-20, 2001.

65. "Phase Behavior and Transitions in Nanostructures Polymers." Poster by H. Duan, S.D. Hudson, M. Holerca and **V. Percec**, International Symposium Nanostructured Liquid Crystals, Kent State University, Kent, OH, June 19-20, 2001, Abstracts, p. 53.
66. "Liquid Crystalline Semiconducting Materials." Poster by I. Shiyanovskaya, K.D. Singer, **V. Percec**, M. Obata, Y. miura, R.J. Tweig, L. Sukhomlinova and V. Gettwert, International Symposium Nanostructured Liquid Crystals, Kent State University, Kent, OH, June 19-20, 2001, Abstracts, p. 197.
67. "Supramolecular Simplicity via Structural Complexity." Invited lecture by **V. Percec**, Gordon Research Conference on polymers (East Coast), Colby Sawyer College, New London, NH, July 8-13, 2001.
68. "A New and Universal Strategy for the Design of Fast Photoconducting and Photorefractive Films and Fibers via Self-Assembly, Co-Assembly and Self-Organization" Invited Lecture by **V. Percec**, Air Force Office of Scientific Research, Chemistry & Life Sciences Directorate, Photorefractive Polymer Review, San Diego, CA, 27-28 July, 2001.
69. "Nanostructured Liquid Crystalline Photorefractive and Semiconducting Materials." Invited Lecture by K.D. Singer, I. Shiyanovskaya, **V. Percec**, M. Obata and Y. Miura, Air Force Office of Scientific Research, Chemistry & Life Sciences Directorate, Photorefractive Polymer Review, San Diego, CA, 27-28 July, 2001, Abstracts, p. 27.
70. "Expanding the 3-D Architectural Diversity of Supramolecular Dendrimers by Functionalization of their Periphery with Libraries of Minidendrons" Invited Lecture by **V. Percec**, ACS Chicago, August 26-30, 2001.
71. "Nature as a Model for the Elaboration of New Concepts in Polymer Science." Invited Lecture by **V. Percec**, Iowa State University, Ames, Iowa August 30, 2001.
72. "New Concepts in NanoBioTechnology." Invited lecture by **V. Percec**, International Symposium: Naobiotech, Muenster, Germany, September 24-27, 2001.
73. "Supramolecular Chirality." Invited Lecture by **V. Percec**, 2<sup>nd</sup> International Symposium "Life Sciences and Materials...Nonbiological Molecules with Biological Functions", September 28-30, 2001, University of Pennsylvania, Philadelphia.
74. "Supramolecular Liquid Crystals" Invited lecture by **V. Percec**, International Symposium on Liquid Crystals to celebrate Anne Marie Levelut, Paris, France, October 4-6, 2001
75. "New Concepts in Supramolecular Dendrimer Chemistry" Key Note Lecture by **V. Percec**, The Second International Dendrimer Symposium, October 14-17, 2001, Tokyo, Japan. Preprints OP11, page 37.

76. "No-Dispersity Polymers by Self-Interrupted Living Radical Polymerizations" Invited Lecture by **V. Percec**, IUPAC International Symposium on Ionic Polymerizations." October 22-26, 2001, Crete, Greece.
77. "New Concepts in Supramolecular Electronic Materials." Invited Lecture by **V. Percec**, October 31st, 2001, LG Chem, Korea.
78. "Dendritic Building Blocks as Biological Mimics." Invited Lecture by **V. Percec**, Technical University of Muenich, Germany, December 17, 2001.
79. "Internal Order and Supramolecular Chirality in Supramolecular Dendrimers." Invited Lecture by **V. Percec**, University of Freiburg, Freiburg, Germany, December 18, 2001.
80. "Nature as a Model For the Elaboration of New Concepts at the Interface Between Organic, Supramolecular and Macromolecular Chemistry." Invited Lecture by **V. Percec**, Max-Planck Institute for Polymer Research, Mainz, Germany, December 19, 2001.
81. "Dendritic Building Blocks as Biological Mimics for the Creation of Order and Supramolecular Chirality." Invited lecture by **V. Percec**, University of Ulm, Ulm, Germany, December 20, 2001.
82. "Plastic and Liquid Crystalline Architectures from Dendritic Receptor Molecules." Poster by J.A.A.W. Elemans, M.J. Boerakker, S.J. Holder, A.E. Rowan, W.-D.Cho, V.Percec, R.J.M. Nolte, Polymer Days Symposium, Netherlands, February 25-26,2002.
83. "Nature as a Model for the Elaboration of New Concepts in Chemistry." Polymer Award Address Lecture by **V.Percec**, Polymer Days Symposium, Netherlands, February 25-26, 2002.
84. "Dendritic Building Blocks as Biological Mimics." Invited lecture by **V. Percec**, Department of Chemistry, Laval University, Quebec City, Canada, March 11, 2002.
85. "Phase behavior and Transitions in Nanostructured Polymers." by H. Duan, P. Kersuwan, S. Hudson and V. Percec, presented at the American Physical Society Meeting, March 18-22, 2002, Indianapolis, IN, *Bull. Am. Phys. Soc.*, **47(1)**, (B33 91) 211(2002).
86. "X-ray Scattering Studies of Fibers of Dendrimeric Molecules." By V.S.K. Balagurusamy, A. Dulcey, U. Edlung, V.Percec, A.A. Hainey, presented at the American Physical Society Meeting, March 18-22, 2002, Indianapolis, IN, *Bull. Am. Phys. Soc.*, **47(2)**, (Q26 10) 940(2002).

87. "Structural Studies of Novel Dendrimeric Liquid Crystals." By P.A. Heiney, W.J. Pao, G. Ungar, Y. Liu, V.S.K. Balagurusamy, W.D. Cho, C. Mitchell, S. Uchida, V. Percec, presented at the American Physical Society Meeting, March 18-22, 2002, Indianapolis, IN, *Bull. Am. Phys. Soc.*, **47(2)**, (Q26 11) 940(2002).
88. "Grazing-Incidence Diffraction Study of Langmuir Films of Amphiphilic Monodendrons." By W.-J. Pao, F. Zhang, P.A. Heiney, W.-D. Cho, C. Mitchell, V.S.K. Balagurusamy, V. Percec, presented at the American Physical Society Meeting, March 18-22, 2002, Indianapolis, IN, *Bull. Am. Phys. Soc.*, **47(2)**, (U 3110) 1172(2002).
89. "Self-Assembling Dendrons as Biological Mimics for the Creation of Order and Chirality." Invited Lecture by V. Percec, Department of Chemistry, Columbia University, New York, April 4, 2002.
90. "Self-Assembling Dendrons as Biological Mimics." Invited lecture by V. Percec, Philadelphia Organic Chemists' Club, April 25, 2002.
91. "Self-Assembling Building Blocks as Biological Mimics. How and What For? Invited lecture by V. Percec, 11<sup>th</sup> Rolduc Polymer Meeting," Crossing Lengthscales and Disciplines: From Macromolecular Structures to Functional Polymer Systems." Rolduc, Netherlands, May 5-8, 2002.
92. "From Nanoscience to Nanotechnology." Invited Lecture by V. Percec, DSM, The Netherlands, May 7, 2002.
93. "Nature as a Model For the Elaboration of New Concepts in Chemistry." Invited Lecture by V. Percec, Naval Research Laboratory, May 28, 2002.
94. "Nonbiological Macromolecules with Biological Functions." Invited Lecture by V. Percec, IUPAC International Symposium on Macromolecules, Beijing, China, July 7-12, 2002.
95. "Self-Assembling Dendrons as Biological mimics for the Creation of Order and Chirality." Invited Lecture by V. Percec, International Conference on Polymer Synthesis, Macro Group UK, University of Warwick, UK, July 29-August 1<sup>st</sup>, 2002. Book of abstracts, p. IL13.
96. "Nature as a Model for the Elaboration of New Concepts in Chemistry." Invited Lecture by V. Percec, DuPont Central research, Wilmington, August 13, 2002.
97. "Self-Assembling Dendrons as Biological Mimics." Invited Lecture by V. Percec, Atofina Central Research, King of Prussia, PA, August 15, 2002.
98. "Self-Assembling Dendrons as Biological Mimics to Investigate the Origins of Order and Chirality." Invited Lecture by V. Percec, A.E. Dulcey, Y. Miura, U. Edlund, M.

Glodde, T.K. Bera, J.G. Rudick, V.S.K. Balagurusamy, S.D. Hudson, P.A. Heine ,  
International Symposium: Directed Self-Assembly: Molecular engineering of  
Polymers, ACS Meeting, Boston, August 18-22, 2002. Polym. Prepr.,

99. "Thermal Degradation of Polyphenylacetylene and of Polypentadeuterophenylacetylene." J.G. Rudick, V. Percec, W. Buchowicz, P. nombel, G. Han, M. Obata. ACS Meeting, Boston, August 18-22, 2002.
100. "Universal strategy to Cylindrical supramolecular Dendrimers Self-Organized in High-Charge Carrier Mobility Materials." By V. Percec, M. Glodde, T.K. Bera, Y. Miura, I. Shiyonovskaya, K.D. Singer, V.S./K. Balagurusamy and P.A. Heiney. ACS Meeting, Boston, August 18-22, 2002.
101. "Monodendron Substituted Poly(ethynylcarbazole)s." by J.G. Rudick, V. Percec and M. Obata. ACS Meeting, Boston, August 18-22, 2002.
102. "Monodendron-Jacketed Polyphenylacetylenes." J.G. Rudick, V. Percec, M. Wagner, M. Obata, V.S.K. Balagurusamy, P.A. Heiney, S. Magonov. ACS Meeting, Boston, August 12-18, 2002.
103. "Solvophobically Driven Self-Assembly of Chiral Supramolecular dendrimers." V. Percec, A.E. Dulcey, Y. Miura, U. Edlund, V.S.K. Balagurusamy, S.D. Hudson, H. Duan, P. Heiney. ACS Meeting, Boston, August 12-18, 2002.
104. " Nonbiological Macromolecules with Biological functions." Invited lecture by V. Percec, University Leuven, Belgium September 16, 2002.
105. "'Nature as a Model for the Elaboration of New Concepts at the Interface Between Organic, Supramolecular and Macromolecular Chemistry." Invited Lecture by V. Percec, International Symposium: Polymer Chemistry for the Design of New Materials, Ghent University, Belgium, September 19-20, 2002; Book of Abstracts, p.L1.
106. "Nature as a Model for the Elaboration of New Concepts in Chemistry." Organic Syntheses Distinguished Lecturer, Department of Chemistry, Colorado State University, Fort Collins, September 30, 2002.
107. "Nature as a Model for the Elaboration of New Concepts in Chemistry." Department of Chemistry, University of Colorado, Boulder, Co., October 1, 2002.
108. "Non-Biological Macromolecules with Biological Functions." Invited Lecture by V. Percec, International Symposium: Macromolecules in the 21<sup>st</sup> Century, October 7-9, 2002, Palais Eschenbach, Vienna, Austria Book of Abstracts p. 25.

109. "Nature as a Model for the Elaboration of new Concepts at the Interface Between Organic, Supramolecular and Macromolecular Chemistry." Invited Lecture by V. Percec, Department of Chemistry, university of Chicago, Chicago, October 18, 2002.
110. "Self-Assembling Dendrons as Biological Mimics." Invited Lecture, 26<sup>th</sup> Annual Symposium on Macromolecular Science and Engineering, University of Michigan, Ann Arbor, October 23, 2002.
111. "Non-Biological macromolecules with Biological Functions." Invited lecture by V. Percec, GelTex, Waltham, MA, November 20, 2002.
112. "From Discotic Liquid Crystals to Dendritic Liquid Crystals." Invited Lecture by V. Percec, International Conference on Discotic Liquid Crystals, International Center for Theoretical Physics, Trieste, Italy, November 25-29, 2002; Book of Abstracts, p. 48.
113. "Thermotropic Structures from Wedge-Shaped Molecules." Invited Lecture by G. Ungar, Y. Liu, X.B. Zeng and V. Percec. International Conference on Discotic Liquid Crystals, International Center for Theoretical Physics, Trieste, Italy, November 25-29, 2002; Book of Abstracts, p. 14.
114. "Non-Biological Macromolecules with Biological Functions." Invited Lecture by V. Percec. Japan-US Seminar; Advanced Polymer Chemistry for the 21<sup>st</sup> Century, December 6-10, 2002, Nagoya, Japan; Book of Abstracts, p. 14.
115. "Non-Biological Macromolecules and Supramolecules with Biological Functions." Weisberger-Williams Lecturer, Eastman Kodak Company, Research and Development Laboratories, Rochester, N.Y., March 11, 2003.
116. "Non-Biological Macomolecules with Biological Functions.' Invited Lecture by V. Percec, ACS Meeting, New Orleans, March 24, 2003.
117. "Self-Assembling Dendrons as Biological Mimics." Invited Lecture by V. Percec, Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, CA, April 16, 2003.
118. "Self-Assembling Dendrons as Biological Mimics." Plenary Lecture by V. Percec, Europolymer Congress 2003, June 23-27, 2003, Stockholm, Sweden, Book of Abstracts
119. "Cell Membrane as a Model for Externally Regulated Supramolecular Membranes" Invited Lecture by V. Percec, ONR Symposium on Membranes, July 14-17, 2003, Baltimore, MD.
120. "Nature as a Model For New Concepts in Polymer Science" Invited lecture, International Symposium on Frontiers in Polymer Chemistry, July 7-8, 2003, Akron, OH.